NON-LINEAR INCREASE OF OXYGEN UPTAKE DURING AN INCREMENTAL EXERCISE TEST: RELATIONSHIP TO PLASMA LACTATE ACCUMULATION AND BLOOD H⁺ CONCENTRATION

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INTRODUCTION

Most of the exercise tests for prediction of the maximal oxygen uptake (VO₂max), exercise tolerance and mechanical efficiency in humans assume a linear relationship between power output (PO) and oxygen uptake (VO₂) (Astrand and Rodahl 1986). On the other hand it is well known that during a constant power output exercise above the lactate threshold there is a continuous rise in VO₂ (see Whipp 1994). It could be expected that in incremental exercise test the VO₂/PO relationship would become curvilinear as blood lactate concentration becomes to accumulate. Recently, Zoladz et al. (1995) have shown that indeed during an incremental exercise test, exceeding the power output corresponding to the lactate threshold is accompanied by an additional rise in VO₂ above that expected from the linear relationship. The observed VO₂ at final power output was 14-17 percent higher than the expected VO₂ at the final power output predicted from the linear relationship of VO₂-power output below the stage of sustained increase in blood lactate concentration.

In order to explore the role of acidosis and plasma lactate accumulation in the increased oxygen cost of high power output exercise, in the present study we investigate the relationship between the magnitude of the additional VO₂ observed at the power output of VO₂max reached during incremental exercise tests in relation to the plasma lactate concentration ([La]ₚᵢ, ) and blood hydrogen ion accumulation (pTjb ).

METHODS

Twelve healthy non-smoking men [aged 22.3 ±1.1 (mean ± S.D ) years], performed an incremental exercise test at 70 rev min⁻¹. The test started at 30 W, followed by an increase of power output (PO) by 30 W every 3 minutes, until exhaustion. Antecubital venous blood samples were taken for lactate [La]ₚᵢ and acid-base balance variables. Plasma lactate concentration [La]ₚᵢ was determined using Automatic Analyser Biochemistry Kodak Ektachem XR 700, (USA). Blood acid base balance variables (pO₂, pCO₂, H⁺, HCO₃⁻) were determined using the system Ciba Corning 248 (England). Oxygen uptake was recorded breath-by-breath using the Oxycon Champion Jaeger (Germany).

RESULTS

Below the lactate threshold (LT) defined in this study as the power output at which a sustained increase in [La]ₚᵢ was observed (at least 0.5 mmol l⁻¹ within 3 minutes), the pulmonary VO₂, showed a linear relationship with PO. However, at a power output above the LT (in this study 135 ± 30 W) there was an additional accumulating increase in the VO₂ above that expected from the PO increase alone. The magnitude of this effect may be illustrated by the difference in the final power output observed at the VO₂max during the incremental exercise test (Obs. PO max at VO₂max) and the expected power output at the VO₂ max (Exp. PO at VO₂max) predicted from the linear VO₂-PO relationship derived from the incremental data below the LT. The Obs. PO max at VO₂max amounting to 270 ± 19 W was 65. 1 ± 35 W (19 %) lower (p<0.01) than the Exp. PO at VO₂max. The mean value of VO₂max reached at the final power output (Obs. PO max )
amounted to 3555 ± 226 ml min⁻¹ and it was 569 ± 269 ml min⁻¹ higher (p<0.01) than the VO₂ expected at this power output, calculated from the linear relationship between VO₂ and PO derived from the incremental data below the LT. This drop in locomotory efficiency expressed by the additional increase in VO₂, amounting to 569 ± 269 ml O₂ min⁻¹, was accompanied by a significant increase in [La]ₚi amounting to 7.04 ± 2.2 mmol L⁻¹, significant increase in blood amounting to 7.4 ± 3 nmol L⁻¹ and a significant drop in blood [HCCVJb amounting to 5.78 ± 1.7 mmol L⁻¹, in relation to the values measured at the lactate threshold power output. We have also correlated the individual values of the additional VO₂ with the variables delta [La]ₚi and delta [I-T]b. The delta values for [La]ₚi and delta [I-T]b were expressed as the differences between values reached at the observed PO max at VO₂max and the LT values. No significant correlation between the additional oxygen uptake and delta [La]ₚi, [H*]b were found.

DISCUSSION

The present study confirmed the early findings (Zoladz et al. 1995) showing that performing a high power output incremental exercise (above the lactate threshold) requires an additional increase of oxygen uptake - above that expected from the linear relationship between the VO₂ and the power output relationship occurring below the lactate threshold. In the present study the mean value of oxygen uptake reached at the maximal power output was 569 ± 269 ml higher (p <0.01) higher than the expected VO₂ calculated on the assumption of a linear relationship between the VO₂ and power output. It was accompanied by a significant increase in plasma lactate and blood H* concentration above the lactate threshold value, amounting to 7.04 ± 2.2 mmol L⁻¹ and 7.37 ± 2.98 nmol L⁻¹, respectively. However, we did not find a significant correlation between the magnitude of the additional increase in VO₂ and the rise in plasma lactate concentration, or the increase in blood H* level developed after the lactate threshold is exceeded. In our study the increase of power output from the lactate threshold level to the maximal power output was accompanied by an increase of the minute ventilation from 49.6 ± 7.3 to 116.8 ±8.91 min⁻¹. On the basis of the data reported by Aaron et al. (1992), one may calculate that a such elevation of VE would increase the respiratory muscle VO₂ by ~ 200 ml. This estimation would suggest that in our study about 1/3 of the additional VO₂ (569 ± 269 ml) observed at the maximal power output could be due to intensification of the exercise hyperpnoe. In conclusion, when performing an incremental exercise test, exceeding the PO corresponding to the LT is accompanied by a significant additional increase in VO₂ above that expected from the linear relationship between VO₂ and power output occurring at the low power output. However, the magnitude of the additional increase in VO₂ does not correlate with the degree of blood lactate concentration and I-T accumulation, reached in the final stage of the incremental test.

REFERENCES


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